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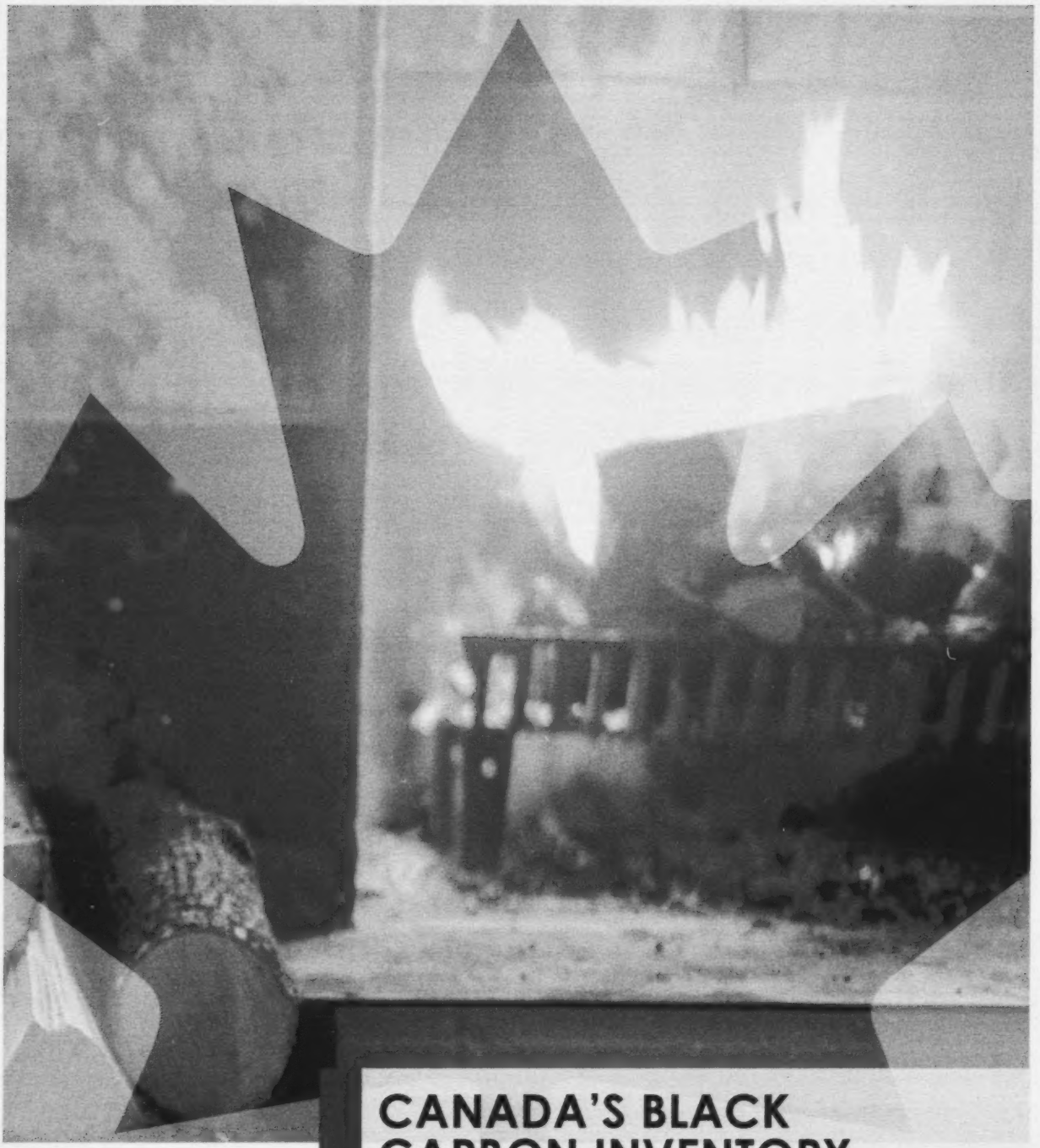

CANADA'S BLACK CARBON INVENTORY

2018 EDITION

Canada

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TABLE OF CONTENTS

Acknowledgements 2

List of Acronyms, Abbreviations and Units 3

Executive Summary 4

1 Introduction 6

1.1 Background on Black Carbon Emission Quantification 6

2 Black Carbon Emissions in Canada 7

2.1 Ore and Mineral Industries 9

2.2 Oil and Gas Industry 10

2.3 Electric Power Generation (Utilities) 11

2.4 Manufacturing 12

2.5 Transportation and Mobile Equipment 12

2.6 Agriculture 13

2.7 Commercial / Residential / Institutional Sources 14

2.8 Trends in Canadian Black Carbon Emissions 15

2.9 Use of Facility Reported Emissions 15

2.10 Recalculations and Completeness 16

2.11 Sources of Uncertainty 16

3 Considerations for Future Editions of this Inventory 17

Annex A: Sector Description 18

Annex B: Black Carbon/$PM_{2.5}$ Ratios 20

Annex C: UNECE Report on Black Carbon Emissions 23

References 24

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LIST OF ACRONYMS, ABBREVIATIONS AND UNITS

APEI	Air Pollutant Emission Inventory
BC	Black carbon
CLRTAP	Convention on Long-range Transboundary Air Pollution
CO_2	Carbon dioxide
ECCC	Environment and Climate Change Canada
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EPG	Electrical Power Generation
IE	Included elsewhere
kg/m^3	Kilograms per cubic metre
kt	Kilotonne
MOVES	Motor Vehicle Emission Simulator
NFR	Nomenclature for Reporting
NPRI	National Pollutant Release Inventory
PIRD	Pollutant Inventories and Reporting Division
PM	Particulate matter
$PM_{2.5}$	Particulate matter less than or equal to 2.5 micrometres in diameter
RESD	Report on Energy Supply and Demand in Canada
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
U.S. EPA	United States Environmental Protection Agency
w/w	Mass fraction (weight by weight)

EXECUTIVE SUMMARY

Black carbon (BC) is a short-lived, small aerosol (or airborne) particle linked to both climate warming and adverse health effects. Black carbon emissions have recently become a focus of attention due to their effects on the near-term warming of the atmosphere and on human health. Reducing black carbon emissions is of particular interest in Polar Regions, such as the Arctic, which are especially sensitive to the effects of black carbon.

The Pan-Canadian Framework on Clean Growth and Climate Change recognizes the importance of reducing emissions of black carbon and other climate pollutants, and the Government of Canada is taking regulatory action to reduce emissions of these pollutants.

During Canada's chairmanship of the Arctic Council (2013–2015), the Council promoted actions to achieve enhanced reductions of black carbon and methane emissions. A framework for action was agreed to in April 2015 that included a commitment from all Arctic states to develop and improve emission inventories for black carbon using, where possible, relevant guidelines from the Convention on Long-range Transboundary Air Pollution (CLRTAP). Environment ministers from Arctic states had previously agreed that these inventories could be voluntarily submitted under the CLRTAP. On November 28, 2017 Canada ratified the Gothenburg Protocol and its 2012 amendments under the CLRTAP. The amendments to the Gothenburg Protocol include new commitments to reduce emissions of particulate matter. The amended Gothenburg Protocol is the first legally binding instrument to include a focus on black carbon, as both a component of particulate matter and as an aerosol.

This report presents the results of Canada's fourth annual inventory of black carbon emissions. Emissions in this inventory are grouped according to the following sources:[1]

- Ore and Mineral Industries
- Oil and Gas Industry
- Electric Power Generation (Utilities)
- Manufacturing
- Transportation and Mobile Equipment
- Agriculture
- Commercial / Residential / Institutional

In 2016, approximately 35 kilotonnes (kt) of black carbon were emitted in Canada, which is less than the revised 2015 emissions of 38 kt (Table ES–1). Transportation and mobile equipment are by far the most important sources of black carbon in Canada, accounting for 19 kt (54%) of total emissions in 2016. Among transportation and mobile equipment, off-road diesel engines account for 8.1 kt (23%) of the total emissions. The other large source in this category is diesel engines used for on-road transport, which account for 5.3 kt (15%) of total emissions.

Commercial/Residential/Institutional sources are the second-largest contributor to black carbon emissions in Canada, representing emissions of 13 kt, or 36% of total emissions in 2016. Home firewood burning is the largest source in this category, representing 12 kt of emissions, or 33% of total 2016 emissions. Wood is an abundant fuel in Canada; it is estimated that 14 million tonnes of wood are burned annually in Canadian homes. More information on the estimation methods can be found in Section 2.2.

Since 2013 black carbon emissions have decreased by 7.8 kt (18%). This overall decrease is attributed to decreases from transportation and mobile equipment, consistent with observed decreasing trends in emissions of fine particulate matter (upon which black carbon estimates are based) (Table ES–1).

The sources included in this fourth annual inventory are estimated to account for at least 90% of anthropogenic black carbon emissions. Work will continue to improve the completeness and accuracy of the inventory, quantifying the emissions that are not captured yet, and refining base data and estimation techniques.

All emissions reported in this inventory are from

[1] Descriptions of sectors within the source categories can be found in Table A–1.

Table ES–1 **Canadian Black Carbon Emissions by Sector (2013–2016)**

Sector	Black Carbon (tonnes)			
	2013	2014	2015	2016
Ore and Mineral Industries	494	456	435	427
Aluminium Industry	**51**	**46**	**37**	**36**
Cement and Concrete Industry	**15**	**16**	**20**	**16**
Foundries	**0.058**	**0.061**	**0.055**	**0.048**
Mining and Rock Quarrying	**429**	**394**	**378**	**375**
Oil and Gas Industry	2 503	2 855	2 799	2 524
Upstream Petroleum Industry	**2 503**	**2 855**	**2 799**	**2 524**
Disposal and Waste Treatment	**5.5**	**6.3**	**5.3**	**4.0**
Heavy Crude Oil Cold Production	**150**	**170**	**184**	**184**
Light Medium Crude Oil Production	**898**	**972**	**880**	**739**
Natural Gas Production and Processing	**804**	**864**	**856**	**789**
Oil Sands In-Situ Extraction and Processing	**260**	**298**	**328**	**335**
Oil Sands Mining, Extraction and Upgrading	**309**	**456**	**477**	**437**
Petroleum Liquids Storage	**4.2**	**3.8**	**3.8**	**2.8**
Petroleum Liquids Transportation	**2.1**	**2.2**	**2.1**	**2.1**
Well Drilling/Servicing/Testing	**70**	**82**	**62**	**32**
Electric Power Generation (Utilities)	212	232	242	243
Coal	**37**	**42**	**39**	**37**
Natural Gas	**12**	**10**	**10**	**8.8**
Diesel	**122**	**135**	**144**	**150**
Other Electric Power Generation	**41**	**45**	**49**	**47**
Manufacturing	493	378	400	329
Pulp and Paper Industry	**269**	**209**	**199**	**191**
Wood Products	**223**	**169**	**201**	**139**
Transportation and Mobile Equipment	26 248	24 616	21 821	18 733
Air Transportation	**681**	**664**	**671**	**684**
Marine Transportation	**2 813**	**2 813**	**1 258**	**1 279**
On-Road Transport	**7 662**	**6 987**	**6 301**	**6 087**
Diesel	**6 808**	**6 204**	**5 533**	**5 290**
Gasoline	**853**	**782**	**767**	**796**
Liquid Petroleum Gas	**0.49**	**0.20**	**0.16**	**0.18**
Compressed Natural Gas	**0.21**	**0.20**	**0.20**	**0.30**
Off-Road Transport	**12 933**	**11 931**	**11 477**	**8 736**
Diesel	**12 283**	**11 267**	**10 820**	**8 145**
Gasoline, Liquid Petroleum Gas, Compressed Natural Gas	**650**	**664**	**657**	**591**
Rail Transportation	**2 160**	**2 222**	**2 114**	**1 948**
Agriculture	23	24	20	20
Fuel Use	**23**	**24**	**20**	**20**
Commercial / Residential / Institutional	12 718	12 704	12 571	12 645
Commercial and Institutional Fuel Combustion	**840**	**897**	**853**	**860**
Construction Fuel Combustion	**42**	**41**	**41**	**43**
Home Firewood Burining	**11 679**	**11 601**	**11 525**	**11 606**
Fireplaces	**3 380**	**3 347**	**3 316**	**3 312**
Furnaces	**4 180**	**4 155**	**4 131**	**4 192**
Wood Stoves	**4 120**	**4 098**	**4 078**	**4 101**
Residential Fuel Combustion	**157**	**165**	**152**	**136**
Total	42 690	41 265	38 288	34 921

anthropogenic (human) sources. Natural sources of black carbon, such as wildfires, are not included.

1 INTRODUCTION

Black carbon (BC) is a short-lived, small aerosol (or airborne) particle linked to both climate warming and adverse health effects. Black carbon emissions have recently become a focus of attention due to their effects on the near-term warming of the atmosphere and on human health. Reducing black carbon emissions is of particular interest in Polar Regions, such as the Arctic, which are especially sensitive to the effects of black carbon. When black carbon particles settle on snow and ice, they darken the surface and enhance absorption of solar radiation, thus increasing the rate of melting.

The Pan-Canadian Framework on Clean Growth and Climate Change recognizes the importance of reducing emissions of black carbon and other climate pollutants, and the Government of Canada is taking regulatory action to reduce emissions of these pollutants.

The Arctic Council was one of the first fora to recognize the importance of taking action to address short-lived climate forcers and pollutants, such as black carbon, methane and ground-level ozone. During Canada's chairmanship (2013–2015), the Council promoted actions to achieve enhanced reductions of black carbon and methane emissions. A key component of these actions is the voluntary reporting by Arctic states of their black carbon emissions to the United Nations Economic Commission for Europe (UNECE), which are based on guidelines for reporting black carbon emissions that were developed under UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). On November 28, 2017, Canada ratified the Gothenburg Protocol and its 2012 amendments under LRTAP. The amendments to the Gothenburg Protocol include new commitments to reduce emissions of particulate matter, and in doing so to prioritize sources of particulate matter that are also significant sources of black carbon.

At the 2015 meeting of Arctic Council ministers, Canada, along with other Arctic states, renewed its commitment to take action to reduce black carbon emissions. As part of this commitment, Canada will continue to improve the quality and transparency of information related to black carbon emissions and to publish national black carbon inventories.

This document describes Canada's fourth annual inventory of anthropogenic black carbon emissions, covering years 2013, 2014, 2015 and 2016. All emissions reported in this inventory are from anthropogenic (human) sources. Natural sources of black carbon such as wildfires are not included.

1.1 Background on Black Carbon Emission Quantification

Black carbon is an aerosol (airborne particle) emitted from combustion processes. Black carbon is not emitted on its own, but as a component of particulate matter less than or equal to 2.5 micrometres in diameter ($PM_{2.5}$), along with other components, such as organic carbon (OC) and inorganic compounds such as sulfates.

Two important assumptions underlie the present inventory: black carbon is predominantly emitted in $PM_{2.5}$; and only $PM_{2.5}$ emissions resulting from combustion contain significant amounts of black carbon. Therefore, the basis for the black carbon inventory is the $PM_{2.5}$ emitted from combustion processes, multiplied by black carbon ratios specific to each type of source. Although important in some cases, $PM_{2.5}$ emissions from non-combustion sources, such as dust raised by traffic on paved and unpaved roads or by wind and machinery on open fields or mine sites, are not considered sources of black carbon.

Black carbon emissions are grouped in the same categories as those used in Canada's Air Pollutant Emission Inventory (APEI); they are organized into seven source categories that are further broken down into 21 sectors and 18 associated subsectors. See Annex A for more details.

The estimates in this inventory are based on the best available information at the time of compilation. Estimates of $PM_{2.5}$ emissions are consistent with those reported in the 2018 Air Pollutant Emission Inventory.

Please refer to the APEI Report (Environment and Climate Change Canada (ECCC) 2018) for a description of estimation methods for $PM_{2.5}$.

Generally, black carbon emissions are calculated using $PM_{2.5}$ emissions from combustion processes and the fraction of black carbon in the $PM_{2.5}$. For example, diesel engines have relatively high emission rates of $PM_{2.5}$ per unit energy, and the fraction of black carbon in these $PM_{2.5}$ emissions is also relatively high. The majority of diesel fuel in Canada is used for mobile sources, particularly in off-road applications. Other combustion sources with high $PM_{2.5}$ emissions include solid fuel combustion units, such as coal- and wood-fired boilers. Industrial sources are generally equipped with highly effective $PM_{2.5}$ controls on boiler emissions, with PM-control efficiencies often in the 90% range. This is reflected in the lower $PM_{2.5}$ emissions compared to other sources. In contrast, the smaller and markedly different equipment used for residential wood combustion (fireplaces, wood stoves or furnaces) have poorer $PM_{2.5}$ -control efficiencies than larger units, notwithstanding the different types of fuel and firing practices used for burning firewood. Given the lower efficiency combined with the lack of treatment of stack gases for many existing residential wood-burning devices, they are by far the largest source of combustion-related $PM_{2.5}$ emissions in Canada. Nonetheless, black carbon emissions from residential wood burning are only one third that of mobile sources due to a lower BC/$PM_{2.5}$ fraction for wood devices than for diesel engines.

The dataset that breaks down the $PM_{2.5}$ emitted from a particular source (e.g. diesel engine emissions) into its different components, including black carbon and organic carbon, is known as a speciation profile. Most speciation profiles contain a fraction for elemental carbon; these fractions are commonly used as a surrogate to quantify black carbon emissions. The current inventory primarily relies on the United States Environmental Protection Agency's (U.S. EPA) SPECIATE database (EPA 2014a) to calculate black carbon emissions from compiled combustion $PM_{2.5}$ emissions. Several BC/$PM_{2.5}$ ratios are specific to the combustion processes or technologies (e.g. appliance types for residential wood combustion), to the fuel type (e.g. diesel, gasoline, natural gas) or to the application (e.g. natural gas use for electrical power generation). Annex B lists all ratios used in this inventory.

Industrial $PM_{2.5}$ emissions originate from both combustion and non-combustion sources; however, only $PM_{2.5}$ emissions resulting from combustion contain significant amounts of black carbon. Where readily available, the $PM_{2.5}$ emissions data from combustion were used in conjunction with BC/$PM_{2.5}$ fractions to estimate black carbon emissions (Table 2–2). Separating combustion from non-combustion sources of $PM_{2.5}$ remains a challenge in some cases due to a lack of data on activities (i.e. quantity of fuel burned) and on non-combustion sources (e.g. rock dust at a mine). In those cases, combustion and non-combustion $PM_{2.5}$ are separated based on the judgement of experts with knowledge of industrial processes.

2 BLACK CARBON EMISSIONS IN CANADA

Approximately 35 kilotonnes (kt) of black carbon were emitted in Canada in 2016 (Table 2–1). Emissions have been grouped according to the following sources:

- Ore and Mineral Industries
- Oil and Gas Industry
- Electric Power Generation (Utilities)
- Manufacturing
- Transportation and Mobile Equipment
- Agriculture
- Commercial / Residential / Institutional

Transportation and mobile equipment sources are by far the most important sources of black carbon in Canada, accounting for 19 kt (54%) of total emissions (Table 2–1). An important source in this category is mobile diesel engines which includes on-road and off-road diesel and accounts for 38% (13 kt) of total emissions. Estimation methods are outlined in Section 2.5.

Commercial/Residential/Institutional sources are the second-largest contributor to black carbon emissions in Canada, representing emissions of 13 kt, or 36 % of total emissions. Home firewood burning is the largest source in this category,

Table 2–1 **Black Carbon Emissions in Canada (2016)**

Sector	Black Carbon (tonnes)	Percentage of Total
Ore and Mineral Industries	427	1.2%
Aluminium Industry	36	0.1%
Cement and Concrete Industry	16	0.0%
Foundries	0.048	0.0%
Mining and Rock Quarrying	375	1.1%
Oil and Gas Industry	2 524	7.2%
Upstream Petroleum Industry	2 524	7.2%
Disposal and Waste Treatment	4.0	0.0%
Heavy Crude Oil Cold Production	184	0.5%
Light Medium Crude Oil Production	739	2.1%
Natural Gas Production and Processing	789	2.3%
Oil Sands In-Situ Extraction and Processing	335	1.0%
Oil Sands Mining, Extraction and Upgrading	437	1.3%
Petroleum Liquids Storage	2.8	0.0%
Petroleum Liquids Transportation	2.1	0.0%
Well Drilling/Servicing/Testing	32	0.1%
Electric Power Generation (Utilities)	243	0.7%
Coal	37	0.1%
Natural Gas	8.8	0.0%
Diesel	150	0.4%
Other Electric Power Generation	47	0.1%
Manufacturing	329	0.9%
Pulp and Paper Industry	191	0.5%
Wood Products	139	0.4%
Transportation and Mobile Equipment	18 733	53.6%
Air Transportation	684	2.0%
Marine Transportation	1 279	3.7%
On-Road Transport	6 087	17.4%
Diesel	5 290	15.1%
Gasoline	796	2.3%
Liquid Petroleum Gas	0.18	0.0%
Compressed Natural Gas	0.30	0.0%
Off-Road Transport	8 736	25.0%
Diesel	8 145	23.3%
Gasoline, Liquid Petroleum Gas, Compressed Natural Gas	591	1.7%
Rail Transportation	1 948	5.6%
Agriculture	20	0.1%
Fuel Use	20	0.1%
Commercial / Residential / Institutional	12 645	36.2%
Commercial and Institutional Fuel Combustion	860	2.5%
Construction Fuel Combustion	43	0.1%
Home Firewood Burning	11 606	33.2%
Fireplaces	3 312	9.5%
Furnaces	4 192	12.0%
Wood Stoves	4 101	11.7%
Residential Fuel Combustion	136	0.4%
Total	34 921	100.0%

representing 12 kt of emissions, or 33% of total emissions. Wood is an abundant fuel in Canada; it is estimated that 14 million tonnes of wood are burned annually in Canadian homes. More information on the estimation methods can be found in Section 2.7.

Improvements are described in Section 2.10, while future refinements are discussed in Section 3.

2.1 Ore and Mineral Industries

Ore and mineral industry sources include primary resource extraction and processing (Table 2–2 and Figure 2–1). For the purpose of this inventory, black carbon emissions were considered for the following industries:

- Aluminium industry
- Cement and concrete industry
- Foundries
- Mining and rock quarrying

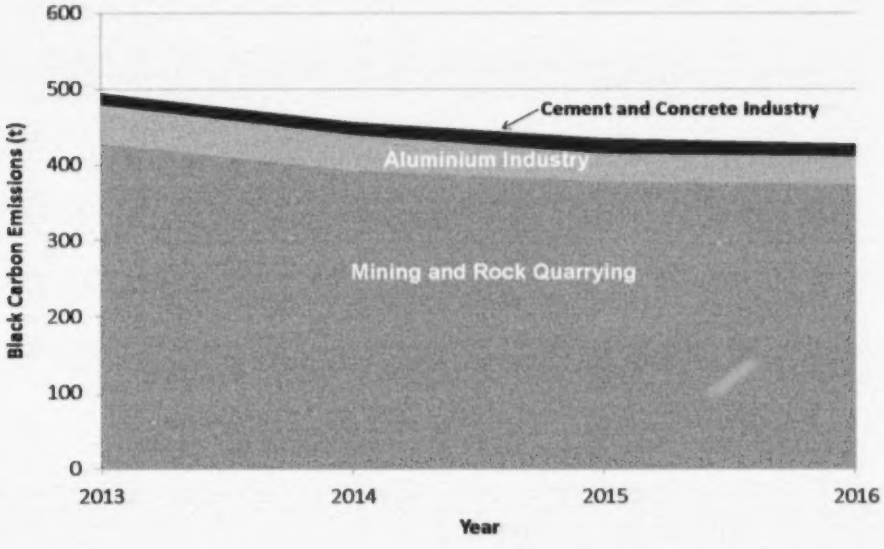
Greater sectoral coverage and further refinement of emissions from ore and mineral industries are expected in future inventories.

Among all ore and mineral industry activities included in this inventory, the mining and rock quarrying industry accounts for the largest proportion (1.1% or 0.4 kt) of total black carbon emissions in 2016 (Figure 2–1). Black carbon

Table 2–2 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from the Ore and Mineral Industries (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Aluminium Industry	2 372	2 142	1 694	1 663	51	46	37	36
Cement and Concrete Industry	766	837	969	820	15	16	20	16
Foundries	6.4	6.7	6.0	5.2	0.058	0.061	0.055	0.048
Mining and Rock Quarrying	1 859	1 986	1 829	1 800	429	394	378	375
Total	5 003	4 972	4 498	4 289	494	456	435	427

Figure 2–1 **Black Carbon Emissions from Ore and Mineral Industries (2013–2016)**



emissions from the mining and rock quarrying sector are larger due to the emissions from remote mines that generate electricity using diesel.

The APEI Report (ECCC 2018) provides more information on the development of $PM_{2.5}$ emission estimates from ore and mineral industries.

2.2 Oil and Gas Industry

Oil and gas industry sources include activities in the upstream petroleum industry (Table 2–3 and Figure 2–2). The following sources are included in this year's report:

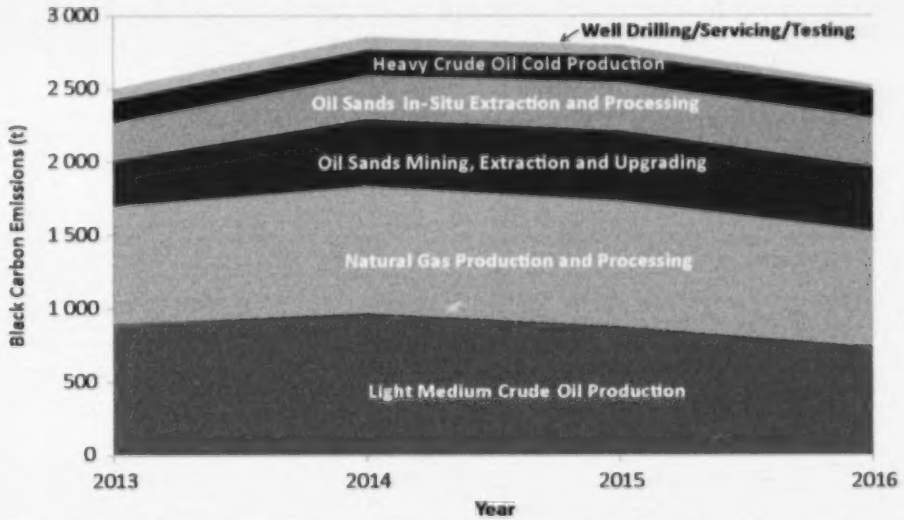
- Disposal and Waste Treatment
- Heavy Crude Oil Cold Production
- Light Medium Crude Oil Production
- Natural Gas Production and Processing
- Oil Sands In-Situ Extraction and Processing
- Oil Sands Mining, Extraction and Upgrading
- Petroleum Liquids Storage
- Petroleum Liquids Transportation
- Well Drilling/Servicing/Testing

The upstream petroleum industry accounts for 2.5 kt or 7.2% of all black carbon emitted

Table 2–3 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from the Oil and Gas Industry (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Upstream Petroleum Industry	8 974	10 748	9 962	8 947	2 503	2 855	2 799	2 524
Disposal and Waste Treatment	23	26	22	17	5.5	6.3	5.3	4.0
Heavy Crude Oil Cold Production	395	476	526	531	150	170	184	184
Light Medium Crude Oil Production	3 389	3 697	3 311	2 732	898	972	880	739
Natural Gas Production and Processing	2 475	2 711	2 669	2 411	804	864	856	789
Oil Sands In-Situ Extraction and Processing	793	925	1 032	1 070	260	298	328	335
Oil Sands Mining, Extraction and Upgrading	1 599	2 562	2 130	2 042	309	456	477	437
Petroleum Liquids Storage	12	11	11	8.1	4.2	3.8	3.8	2.8
Petroleum Liquids Transportation	5.7	6.0	5.9	5.6	2.1	2.2	2.1	2.1
Well Drilling/Servicing/Testing	283	335	255	131	70	82	62	32
Total	8 974	10 748	9 962	8 947	2 503	2 855	2 015	2 524

Figure 2–2 **Black Carbon Emissions from Oil and Gas Industry (2013–2016)**



in 2016. Among all of the upstream petroleum industry sources included in this inventory, natural gas production and processing accounts for the largest proportion (0.79 kt or 2.3%) of black carbon emissions in 2016 (Figure 2–2).

The next largest source of black carbon emissions in this category is light medium crude oil production, which accounts for 0.74 kt or 2.1% of overall black carbon emissions.

2.3 Electric Power Generation (Utilities)

Electric power generation (utilities) sources include the combustion of coal, natural gas and other fuels for the purpose of generating electricity (Table 2–4).

Electric power generation accounts for 0.24 kt (0.7%) of all black carbon emissions in 2016 (Table 2–4 and Figure 2–3). Black carbon emissions from electric power generation are low because large facilities using solid fuels are equipped with particulate controls. Emissions of $PM_{2.5}$ from liquid and gaseous fuels from boilers and heaters are low. There is relatively little diesel fuel used in large stationary electricity generation applications. Coverage for this sector is nearly

Table 2–4 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from Electric Power Generation (Utilities) (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Coal	2 205	2 468	2 322	2 178	37	42	39	37
Natural Gas	475	387	386	351	12	10	10	8.8
Diesel	158	175	187	195	122	135	144	150
Other	313	412	419	498	41	45	49	47
Total	3 152	3 443	3 313	3 222	212	232	242	243

Figure 2–3 **Black Carbon Emissions from Electric Power Generation (Utilities) (2013–2016)**

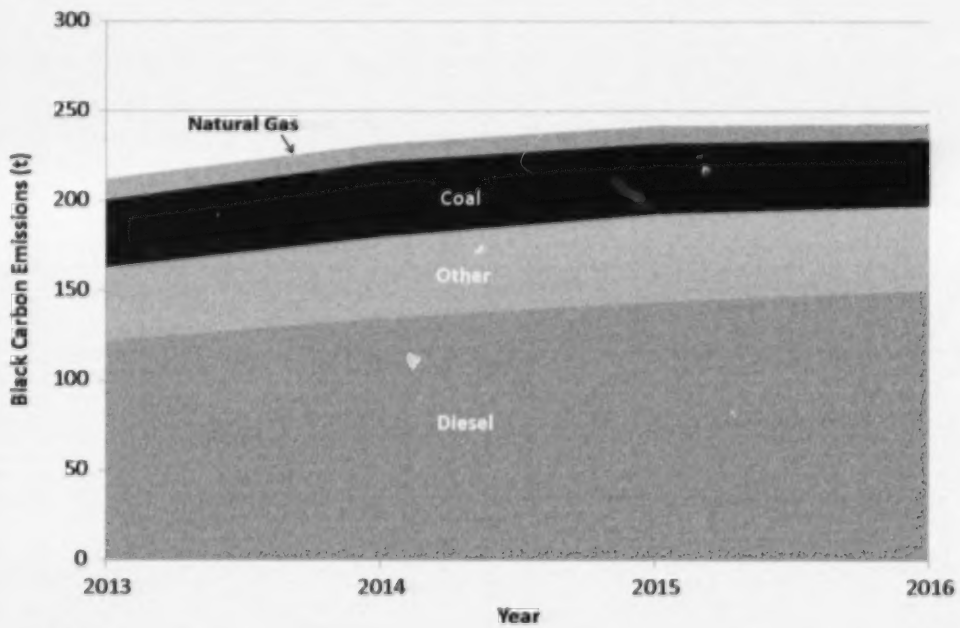


Table 2–5 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from Manufacturing (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Pulp and Paper Industry	8 195	7 554	6 874	6 318	269	209	199	191
Wood Products	3 215	2 508	2 828	2 163	223	169	201	139
Total	11 409	10 062	9 701	8 481	493	378	400	329

complete; the remaining small sources (smaller facilities including those in remote communities that do not report their emissions to the National Pollutant Release Inventory) will be addressed in future inventories. Emissions from these sources, though small nationally, can have important regional warming and air quality impacts in such areas as Canada's North.

The largest emitter of black carbon in this category is diesel which accounts for 0.15 kt (0.4%) of overall black carbon emissions in 2016.

2.4 Manufacturing

Manufacturing sources include the pulp and paper and wood product industries (Table 2–5). This category contributes to 0.33 kt or 0.9% of overall black carbon in 2016; wood products contribute 42% while pulp and paper contribute 58% to the manufacturing related black carbon emissions in 2016. While there are other manufacturing sectors, only those with significant $PM_{2.5}$ emissions as a result of combustion were included in this inventory.

Although the 2016 combustion emissions of $PM_{2.5}$ from manufacturing sources (8.5 kt; see Table 2–5) are approximately double those from ore and mineral industry sources, black carbon emissions from ore and mineral industry sources are comparable to those from manufacturing sources (0.3 kt and 0.4 kt, respectively). This is due to the lower BC to $PM_{2.5}$ ratio specific to manufacturing sources of $PM_{2.5}$, compared to the Black Carbon (BC) to $PM_{2.5}$ ratio for ore and mineral industry sources.

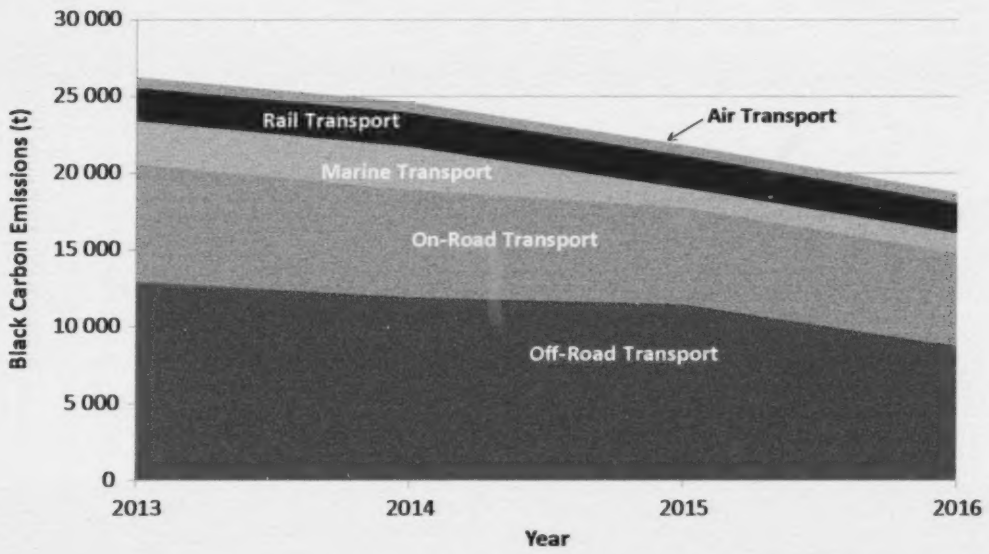
2.5 Transportation and Mobile Equipment

Transportation and mobile equipment includes air transportation, marine transportation, on-road transportation (diesel, gasoline, liquid petroleum gas, and compressed natural gas), off-road transportation (diesel, gasoline, liquid petroleum gas, and compressed natural gas), and rail transportation (Table 2–6 and Figure 2–4). Off-road transport is a highly diverse source that includes lawn and garden equipment, recreational vehicles such as

Table 2–6 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from the Transportation and Mobile Equipment (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Air Transportation	884	862	871	888	681	664	671	684
Marine Transportation	13 323	13 323	4 689	4 828	2 813	2 813	1 258	1 279
On-Road Transport	14 388	13 179	12 042	11 792	7 662	6 987	6 301	6 087
Diesel	10 660	9 807	8 767	8 391	6 808	6 204	5 533	5 290
Gasoline	3 725	3 370	3 273	3 399	853	782	767	796
Liquid Petroleum Gas	2.3	0.84	0.64	0.76	0.49	0.20	0.16	0.18
Compressed Natural Gas	1.1	1.0	1.0	1.5	0.21	0.20	0.20	0.30
Off-Road Transport	20 488	19 265	18 647	14 761	12 933	11 931	11 477	8 736
Diesel	15 607	14 317	13 749	10 349	12 283	11 267	10 820	8 145
Gasoline, Liquid Petroleum Gas, Compressed Natural Gas	4 881	4 948	4 899	4 412	650	664	657	591
Rail Transportation	2 801	2 881	2 741	2 526	2 160	2 222	2 114	1 948
Total	51 883	49 509	38 991	34 795	26 248	24 616	21 821	18 733

Figure 2–4 **Black Carbon Emissions for the Transportation and Mobile Equipment Sector (2013–2016)**



pleasure craft and snowmobiles, farm equipment, construction and mining equipment, and portable generators and pumps. Both on-road and off-road diesel engines are subject to emission standards for particulate matter and are equipped with sophisticated emission controls to reduce particulate matter. As more new engines equipped with this technology replace older, more polluting engines, it is expected that emissions of particulate matter will decrease.

Transportation and mobile equipment sources are by far the most important sources of black carbon in Canada, accounting for 19 kt (54%) of total emissions (Table 2–1). An important source in this category is mobile diesel engines which includes on-road and off-road diesel and accounts for 38% (13 kt) of total emissions (Figure 2–5). Larger sources of black carbon are those that either emit large quantities of $PM_{2.5}$, or those for which the $BC/PM_{2.5}$ fraction is large. Mobile diesel engines emit significant quantities of $PM_{2.5}$ and have the highest $BC/PM_{2.5}$ fractions of all black carbon sources (Table 2–6). As a result, mobile diesel engines account for nearly all emissions from this category, or about half of total black carbon emissions. The remaining black carbon emissions from transportation and mobile equipment sources come from air, marine, non-diesel on and off-road transport and rail transportation which account for 5.3 kt and 15% of overall black carbon emitted in 2016.

To estimate emissions from mobile sources, bottom-up approaches were adopted, i.e. applying emission factors to disaggregated activity data, such as vehicle or equipment data sorted by class, age or model year and fuel type. In all cases $PM_{2.5}$ was estimated first and $PM_{2.5}$-to-black carbon ratios were subsequently applied. The methods for estimating $PM_{2.5}$ emissions from mobile sources are described in the Air Pollutant

Table 2–7 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from Agriculture (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Fuel Use	**281**	**294**	**257**	**251**	**23**	**24**	**20**	**20**
Total	281	294	257	251	23	24	20	20

Emission Inventory Report (Environment and Climate Change Canada 2017).

2.6 Agriculture

Agriculture sources consist of fuel use for non-mobile equipment, e.g. for drying grain, and account for 0.02 kt (0.1%) of overall black carbon emitted in 2016 (Table 2–7). Estimates for these sources are based on the fuel type and quantity consumed in Canada and the corresponding BC/$PM_{2.5}$ fraction. For this sector, there is a lower BC to $PM_{2.5}$ ratio specific to agricultural fuel use.

2.7 Commercial / Residential / Institutional Sources

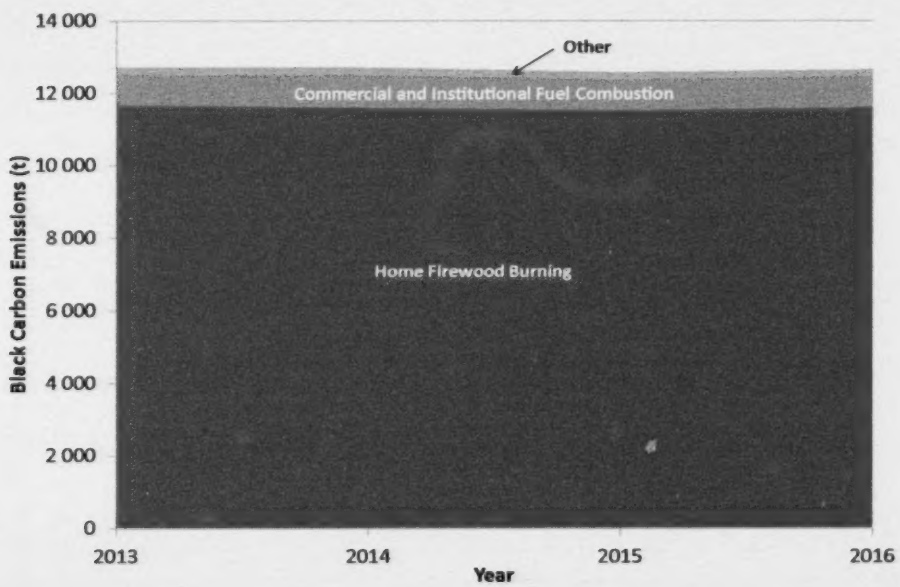
Commercial / Residential / Institutional sources include home firewood burning, fuel combustion in commercial and institutional buildings, in construction sites, and in homes. The majority of emissions from these sources are due to combustion in large, relatively efficient commercial boilers, or in small, less-efficient residential fireplaces and woodstoves.

Among all commercial / residential / institutional sources, home firewood burning accounts for the largest proportion (11.6 kt or 33%) of black carbon

Table 2–8 **Emissions of Combustion $PM_{2.5}$ and Black Carbon from Commercial / Residential / Institutional Components (2013–2016)**

Sector	$PM_{2.5}$ from combustion (tonnes)				Black Carbon (tonnes)			
	2013	2014	2015	2016	2013	2014	2015	2016
Commercial and Institutional Fuel Combustion	2 392	2 558	2 356	2 355	840	897	853	860
Construction Fuel Combustion	117	116	117	120	42	41	41	43
Home Firewood Burning	164 707	163 566	162 465	163 258	11 679	11 601	11 525	11 606
Fireplaces	60 577	60 000	59 433	59 365	3 380	3 347	3 316	3 312
Furnaces	30 290	30 106	29 934	30 380	4 180	4 155	4 131	4 192
Wood Stoves	73 840	73 460	73 098	73 513	4 120	4 098	4 078	4 101
Residential Fuel Combustion	2 406	2 526	2 362	2 120	157	165	152	136
Total	169 622	168 766	167 300	167 853	12 718	12 704	12 571	12 645

Figure 2–5 **Black Carbon Emissions for Commercial / Residential / Institutional Sector (2013–2016)**



emissions in 2016 (Table 2–8 and Figure 2–5). Emissions from home firewood burning are grouped according to the following categories:

- Fireplaces
- Furnaces
- Wood Stoves

A key determinant of total emissions from home firewood burning is the quantity of wood burned in each type of wood-burning device (residential wood stoves, furnaces, and fireplaces). Wood furnaces emit the highest concentration of $PM_{2.5}$ and black carbon.

The next largest source of black carbon emissions in this category is commercial and institutional fuel combustion, which accounts for 0.86 kt (2.5%) of overall black carbon emissions.

Overall, the combustion of fuels other than wood accounts for 1.04 kt (3.0%) of the total black carbon emissions in 2016 from this category. Estimations for these sources are based on the fuel type and quantity consumed in Canada and the corresponding BC/$PM_{2.5}$ fraction for each sector.

2.8 Trends in Canadian Black Carbon Emissions

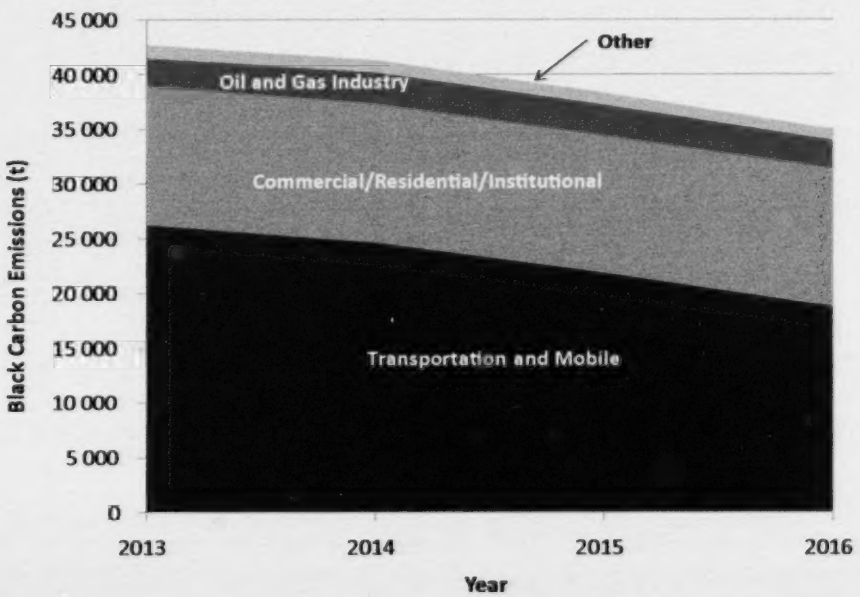
Since 2013 black carbon emissions have shown a general decreasing trend of 7.8 kt (18%) (Figure 2–6). This overall decrease is attributed to decreases from transportation and mobile equipment, consistent with observed decreasing trends in emissions of fine particulate matter (upon which black carbon estimates are based).

The Commercial/Residential/Institutional Sector has remained relatively steady since 2013 with emissions ranging from 12.6 kt to 12.7 kt (30-36 % of total BC emissions). Oil and Gas Industry and Electric Power Generation (EPG) Sectors are the two sectors that have shown an increase in emissions. The Oil and Gas Industry emissions peaked in 2014 at 2.9 kt and have since decreased to levels similar to those in 2013 of 2.5 kt. Black carbon emissions from EPG have increased from 0.21 to 0.24 kt between 2013 and 2016.

2.9 Use of Facility Reported Emissions

Only emissions of $PM_{2.5}$ resulting from combustion contain significant amounts of black carbon. In

Figure 2–6 **Trends in Canadian Black Carbon Emissions (2013–2016)**



the Air Pollutant Emission Inventory, $PM_{2.5}$ emission estimates are calculated using a variety of data sources, notably emission estimates reported by Canadian facilities to the National Pollutant Release Inventory (NPRI). For sources that are incompletely covered by $PM_{2.5}$ estimates reported to the NPRI, $PM_{2.5}$ emissions are quantified using activity data, statistics and emission factors. For this inventory, all industrial source emissions are estimated using facility data, except in the upstream oil and gas industry, where facility-reported data are used in combination with the results of an independent study. Within non-industrial sources, electric power generation is estimated using facility data, while emissions due to agricultural, construction and residential (wood and other) fuel combustion are estimated from data on fuel consumption and combustion technologies. Commercial fuel combustion is estimated using a combination of facility-reported and other data sources.

Stack emissions of $PM_{2.5}$ reported by facilities form the basis of the black carbon estimation. For each individual stack, the appropriate black carbon speciation factor (or factors) was applied to the combustion related $PM_{2.5}$ (Annex B). The emissions are then summed at the facility level and aggregated to form the sectoral emission estimate.

2.10 Recalculations and Completeness

As new data and methodologies become available, emission estimates from previous inventory editions are recalculated. This fourth edition of the black carbon inventory has been developed largely based on the same methodologies as the previous edition, with the exception of Upstream Petroleum Industry (Table 2–9).

A quantitative assessment of completeness is challenging, because detailed analyses have not been completed for all sources. The sources included in this inventory are estimated to account for at least 90% of anthropogenic black carbon emissions in Canada, since the largest combustion sources as well as those with little $PM_{2.5}$ control measures are accounted for. An estimate of the sectoral coverage is included in the following tables, and efforts will be made in coming inventories to expand the sectoral coverage.

2.11 Sources of Uncertainty

A key source of uncertainty with black carbon inventories is the inconsistencies between definitions and measurements of black carbon (Bond et al. 2013). Scientists use different methods to measure black carbon particle emissions at the source and in the atmosphere, and therefore measured quantities are not strictly comparable.

Although not quantified, uncertainty about black carbon estimates in this inventory is primarily

Table 2–9 **Summary of Methodological Changes or Refinement**

Description	Impact on Emissions
Upstream Petroleum Industry	
Previously, the proportion of $PM_{2.5}$ emissions from combustion and process sources in the Oil Sands Mining, Extraction and Upgrading sector were estimated using stack data from the NPRI. However, assumptions were necessary regarding the types of fuel being combusted in order to estimate BC emissions. The recently completed inventory of emissions from the Oil Sands Industry (ECCC 2017) breaks down combustion emissions by fuel type for the various oil sands mining and upgrading facilities. This study was used to split $PM_{2.5}$ emissions between combustion and process sources and to allocate NPRI reported emissions to the appropriate fuel type allowing for the proper BC fraction to be used. Additionally, new data sources for flared and fuel gas volumes were identified and used to estimate $PM_{2.5}$ emissions for Alberta, British Columbia and Saskatchewan.	Changes to the method used to estimate emissions from Oil Sands Mining, Extraction and Upgrading resulted in emissions decreases of -200 t (or -39%) in 2013, -403 t in 2014 (or -47%) and -119 t (or -20%) in 2015. Changes to the flaring activity data resulted in increases in black carbon emissions of +219 t (+22%) in 2013, +332 t (+31%) in 2014 and +399 t (+44%) in 2015. Changes to the fuel gas activity data resulted in emission changes of +118 t (+13%), +108 t (+12%) and -3 t (-0.3%) in 2013, 2014, and 2015 respectively.

driven by the uncertainty with the $BC/PM_{2.5}$ ratios. There is large variability in the size of measurement samples used to derive these ratios; the same ratios can be by default applied to several different technologies. An example of the limitation in available $BC/PM_{2.5}$ ratios is demonstrated with the application of the diesel $BC/PM_{2.5}$ ratio for aviation turbo fuel in jet aircrafts, as there is no available ratio specific to aviation turbo fuel. Similarly, a single $BC/PM_{2.5}$ ratio is applied to all residential wood combustion appliances except wood furnaces (Annex C, Table C-1). The refinement of $BC/PM_{2.5}$ ratios is dependent on new measurements.

The uncertainty is high in determining the proportion of $PM_{2.5}$ emissions that arise from combustion emissions for industrial sources. The primary data source for estimating $PM_{2.5}$ emissions from many industrial sources is the National Pollutant Release Inventory (NPRI), in which emissions are reported by facilities by stack or as one aggregate value for the facility as a whole and are not broken down between combustion and non-combustion emissions. Engineering knowledge was necessary to attribute a ratio to each sector, with varying degrees of accuracy.

3 CONSIDERATIONS FOR FUTURE EDITIONS OF THIS INVENTORY

This inventory is estimated to provide 90% coverage of Canadian black carbon emissions. Future improvements will focus on expanding current coverage, as well as improving the accuracy of emission estimates. In particular, the incorporation of emissions from diesel engines used for electricity generation in remote locations (not currently reporting emissions to the National Pollutant Release Inventory) will be explored.

Another source not currently estimated is prescribed burning, which is the controlled and intentional burning of biomass as a land management practice. Although it is not expected to be a large source of emissions for Canada, it will be included in future inventories.

ANNEX A: **SECTOR DESCRIPTION**

ANNEX B: **BLACK CARBON/ $PM_{2.5}$ RATIOS**

ANNEX C: **UNECE REPORT ON BLACK CARBON EMISSIONS**

ANNEX A: **SECTOR DESCRIPTION**

Sectors that are estimated for black carbon emissions are listed in Table A–1.

Table A–1 **Sector Description**

Ore and Mineral Industries	
Aluminium Industry	Alumina production through bauxite refining, primary aluminium production through smelting and refining and secondary aluminium production in which aluminium is recovered from aluminium-containing scrap.
Cement and Concrete Industry	Emissions from the entire process of cement and lime production in rotary kilns, and the preparation of ready-mix concrete and gypsum products.
Foundries	Emissions from facilities for the production of castings of various types of ferro-alloys and small iron and steel foundries not associated with integrated iron and steel facilities. The types of foundries included are: open ferrous, electric arc and induction foundries.
Mining and Rock Quarrying	Emissions from overburden removal, drilling in rock, blasting, loading of materials, transporting raw materials by conveyors or haulage trucks, scraping, bulldozing, grading, open storage pile losses and wind erosion from exposed areas.
Oil and Gas Industry	
Upstream Petroleum Industry	
Disposal and Waste Treatment	Emissions from the treatment and disposal of any oilfield or processing waste fluids or produced water. Typically injected into a disposal well.
Heavy Crude Oil Cold Production	Emissions from the production of crude oil which does not involve the use of any thermal techniques. Heavy crude oil is a category of crude oil characterized by relatively high viscosity, a higher carbon-to-hydrogen ratio, and a relatively higher density – typically 900 kg/m^3 or more (25° or less API). Heavy crude oil typically is more difficult to extract with conventional recovery techniques and is more costly to refine.
Light Medium Crude Oil Production	Emissions from the production of crude oil characterized by relatively low viscosity, a lower carbon-to-hydrogen ratio, and a relatively lower density – typically less than 900 kg/m^3 (greater than 25° API).
Natural Gas Production and Processing	Emissions from the removal of undesired constituents of raw natural gas such as helium, ethane, natural gas liquids (NGLs), water, H_2S and CO_2 to upgrade the quality of the natural gas to meet contract specifications. May also include the fractionation of mixed NGLs to natural gas products and possibly adjusting the heating value by the addition or removal of nitrogen. Emissions from the production of a naturally occurring mixture of hydrocarbon and non-hydrocarbon compounds existing in the gaseous phase or in solution with hydrocarbon liquids in geologic formations beneath the earth's surface. The principal hydrocarbon constituent is methane.
Oil Sands In-Situ Extraction and Processing	Emissions from the recovery of bitumen or heavy oil from a reservoir using a series of wells and thermal techniques.
Oil Sands Mining, Extraction and Upgrading	Emissions from the recovery of bituminous sands using open pit mining techniques, the extraction of bitumen from the mined ore through hot water and hydrocarbon solvent extraction, and the upgrading of bitumen into synthetic crude oil.
Petroleum Liquids Storage	Emissions from the storage of liquid hydrocarbons (i.e. crude oil, diluted bitumen, natural gas liquids, condensate, etc.) including storage tank losses, loading/unloading and handling losses.
Petroleum Liquids Transportation	Emissions from the transportation by pipeline, truck, rail and ship of liquid hydrocarbons, but does not include emissions from the vehicles themselves.
Well Drilling/Servicing/Testing	Emissions from the process of drilling wells. Emissions from diesel engines used to power the rigs are included in the off-road use of diesel. Emissions from work performed on a well after its initial completion for repair or to increase production rates. Emissions from diesel engines used to power the rigs are included in the off-road use of diesel. Emissions from flow testing conducted to determine the deliverability of a well. (Sometimes the test may be conducted into a flow or gathering line; however, more often the liquids are produced into temporary tankage brought on site for the test, and the gas phase is either vented or flared.)
Electric Power Generation (Utilities)	
Coal	Electric power generation from combustion of coal by utilities and by industry for commercial sale and/or private use.
Natural Gas	Electric power generation from combustion of natural gas by utilities and by industry for commercial sale and/or private use.
Diesel	Electric power generation from combustion of diesel by utilities and by industry for commercial sale and/or private use.
Other	Electric power generation from other energy sources by utilities and by industry for commercial sale and/or private use.
Manufacturing	
Pulp and Paper Industry	Emissions from chemical, mechanical, recycling and semi-chemical mills, including the production of energy through the combustion of spent pulping liquor, biomass and fossil-fuel combustion. Also includes fugitive emissions from wood refining, screening and drying, and various steps in chemical recovery systems.
Wood Products	Emissions from Sawmills, Panel board mills (including veneer, plywood, waferboard, particle board and medium-density fiberboard mills), and Other wood products (including furniture and cabinet makers, wood treating plants, wood pellet mills and Masonite manufacturers).

Transportation and Mobile Equipment	
Air Transportation	Commerical, general and military aircraft using aviation gasoline or aviation turbo fuel.
Marine Transportation	Emissions from marine craft in anchored, berth and underway phases.
On-Road Transport – Diesel	Emissions from diesel road vehicles, including light- and heavy-duty trucks, and automobiles.
On-Road Transport – Gasoline	Emissions from gasoline road vehicles, including light- and heavy-duty trucks, automobiles and motorcycles.
On-Road Transport – Liquid Petroleum Gas	Emissions from propane road vehicles, including light- and heavy-duty trucks, automobiles.
On-Road Transport – Compressed Natural Gas	Emissions from natural gas road vehicles, including light- and heavy-duty trucks, automobiles.
Off-Road Transport – Diesel	Off-road vehicles and mobile equipment using diesel fuel in mining, construction, agriculture, commercial purposes, logging, railway maintenance, airport ground support, and lawn and garden equipment, along with recreational vehicles.
Off-Road Transport - Gasoline, Liquid Petroleum Gas, Compressed Natural Gas	Emissions from off-road vehicles using gasoline, liquid petroleum gas and compressed natural gas, including 2- and 4-stroke mining, construction, recreational, agricultural, commercial, logging, railway maintenance, airport ground support, and lawn and garden equipment.
Rail Transportation	Emissions from freight and passenger trains, including yard-switching activities.
Agriculture	
Fuel Use	Emissions from stationary combustion sources in agricultural facilities such as space and water heating and crop drying.
Commercial / Residential / Institutional	
Commercial and Institutional Fuel Combustion	Emissions resulting primarily from external combustion sources used for space/water heating in commercial establishments, health and educational institutions and government/public administration facilities.
Construction Fuel Combustion	Emissions from stationary combustion sources at construction sites such as power generators, heaters, and boilers.
Home Firewood Burning	
Fireplaces	Emissions from residential fireplaces, both sealed and open units.
Furnaces	Emissions from wood furnaces, particularly from larger, exterior units.
Wood Stoves	Emissions from residential woodstoves burning both firewood and wood pellets.
Residential Fuel Combustion	Emissions resulting primarily from combustion of fossil fuels used for space/water heating in residences.

ANNEX B: **BLACK CARBON/$PM_{2.5}$ RATIOS**

The ratios used to convert $PM_{2.5}$ emissions to black carbon emissions are listed in Table B–2 through Table B–7.

Table B–1 **Black Carbon/$PM_{2.5}$ Ratios for Ore and Mineral Industries Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Aluminium Industry	Alumina (Bauxite Refining)	Aluminum Processing, baghouse (avg)	0.020165	2910110, 291012.5, 2910130 and 29101C	Average of 4 speciation factors from EPA 2014a
		Lime Kiln	0.00576	2320230	EPA 2014a
	Primary Aluminum Smelting & Refining	Aluminum Processing, baghouse (avg)	0.020165	2910110, 291012.5, 2910130 and 29101C	Average of 4 speciation factors from EPA 2014a
		Aluminum Reduction Potline	0.0268	2910210	EPA 2014a
		Coal Combustion	0.021321	4373	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.02043		Weighted average (excluding Coal Combustion)
	Secondary Aluminum (Includes Recycling)	Secondary Aluminum – Dross Recovery Furnace	0.01426	2010310 201032.5 2010330 20103C	EPA 2014a
Cement and Concrete Industry	Cement Manufacture	Cement Kiln (Coal-Fired)	0.002	2720310	EPA 2014a
		Cement Kiln	0.027801	4331	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.02778		Weighted average
	Concrete Batching & Products	Cement industry	0.0017	3677	EPA 2014a
	Lime Manufacture	Lime Kiln	0.00464	23202C	EPA 2014a
		Cement Kiln	0.027801	4331	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.00511		Weighted average
	Gypsum Product Manufacturing	Mineral Products – Avg – Composite	0.01467	91120	EPA 2014a
Foundries	Die Casting	Cast Iron Cupola – Composite	0.0091	91157	EPA 2014a
	Ferrous Foundries	Cast Iron Cupola – Composite	0.0091	91157	EPA 2014a
	Non-ferrous Foundries	Primary Metal Production – Average	0.01002	9000730	EPA 2014a
Mining and Rock Quarrying	Coal Mining Industry	Mineral Products – Avg – Simplified	0.01467	92120	EPA 2014a
	Metal Mining	Incinerator (avg)	0.06658	3286 3287 3288 3290	EPA 2014a
		Diesel Exhaust	0.77124	3914	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.06658	3286 3287 3288 3290	EPA 2014a
	Potash	Phosphate Manufacturing – Composite	0.0274	91165	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.0274	91165	EPA 2014a
	Rock, Sand and Gravel	Sand	0.00265	3665	EPA 2014a
	Silica Production	Mineral Products – Avg – Simplified	0.01467	92120	EPA 2014a
	Limestone	Mineral Products – Avg – Simplified	0.01467	92120	EPA 2014a
	Other Minerals	Mineral Products – Average	0.01537	9001310 900132.5 9001330 90013C	EPA 2014a
		Natural Gas Combustion – Simplified	0.384	92112	EPA 2014a
		Oil Combustion	0.42997	3864	EPA 2014a
		Diesel Exhaust	0.77124	3914	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.13074		Weighted average

Table B–2 **Black Carbon/$PM_{2.5}$ Ratios for Oil and Gas Industry Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Upstream Petroleum Industry		Diesel Exhaust	0.77124	3914	EPA 2014a
		Natural Gas Combustion – Simplified	0.384	92112	EPA 2014a
		Flaring	0.24	-	McEwen (2013)

Table B–3 **Black Carbon/$PM_{2.5}$ Ratios for Electric Power Generation (Utilities) Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Coal		Bituminous Coal Combustion – Simplified	0.01696	92104	EPA 2014a
Natural Gas		Gas-Fired Combined Cycle and Cogeneration Plants	0.025	5671	EPA 2014a
Diesel		Diesel Exhaust	0.77124	92106	EPA 2014a
Other Electric Power Generation		Residual Oil Combustion	0.01	4737	EPA 2014a
		Bunker C and Natural Gas	0.197	4737 92112	EPA 2014a
		Distillate Oil Combustion	0.1	4736	EPA 2014a
		Gas-Fired Combined Cycle and Cogeneration Plants	0.025	5671	EPA 2014a
		Wood Fired Boiler – Simplified	0.037088024	92114	EPA 2014a
		Oil Combustion	0.429969	3864	EPA 2014a

Table B–4 **Black Carbon/$PM_{2.5}$ Ratios for Manufacturing Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Pulp and Paper	Pulp and Paper Industry	Kraft Recovery Furnace – Simplified	0.0153	92119	EPA 2014a
		Wood-Fired Boiler – Simplified	0.03709	92114	EPA 2014a
		Residual Oil Combustion	0.01	4737	EPA 2014a
		Hog fuel and bunker crude use	0.03167	92114 (80%) 4737 (20%)	EPA 2014a
		Cement Kiln	0.027801	4331	EPA 2014a
		Lime Kiln	0.00464	23202C	EPA 2014a
		Gas-Fired Combined Cycle and Cogeneration Plants	0.025	5671	EPA 2014a
		Oil-Fired Boilers	0.071	5672	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.02827		Weighted average
	Converted Paper Product Manufacturing (TBA)	Pulp & Paper Mills – Simplified	0.001	92144	EPA 2014a
Wood Products	Sawmills	Wood-Fired Boiler – Simplified	0.03709	92114	EPA 2014a
		Wood Products – Sawing – Simplified	0.038	92131	EPA 2014a
	Panel Board Mills	Wood-Fired Boiler – Simplified	0.03709	92114	EPA 2014a
		Wood Products – Drying – Composite	0.08	91128	EPA 2014a
		Composite wood and natural gas boilers	0.21054	91114 91112	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.0897		Weighted average
	Other Wood Products	Wood-Fired Boiler – Simplified	0.03709	92114	EPA 2014a
		Wood Products – Drying – Composite	0.08	91128	EPA 2014a
		Average of large stack $BC/PM_{2.5}$ fractions	0.03784		Weighted average

Table B–5 **Black Carbon/$PM_{2.5}$ Ratios for Transportation and Mobile Equipment Source Emission Calculations**

Sector	$BC/PM_{2.5}$ fractions		Profile	Reference
	Description	Value (w/w)		
Air Transportation	Aviation Turbo Fuel (Jet A or B)	0.771241	92106	EPA 2014a
	Aviation Gasoline	0.12178	92113	EPA 2014a
Marine Transportation	Heavy Fuel Oil	0.12		EMEP/EEA (2013), Table A_7
	Marine Diesel Oil	0.771241	92106	EPA 2014a
	Marine Gasoline Oil	0.771241	92106	EPA 2014a
On-Road Transport	Diesel	EC data extracted from MOVES model; values are variable according to model input and vehicle class		EPA 2014b
	Gasoline	EC data extracted from MOVES model; values are variable according to model input and vehicle class		EPA 2014b
	Liquid Petroleum Gas	EC data extracted from MOVES model; values are variable according to model input and vehicle class		EPA 2014b
	Compressed Natural Gas	EC data extracted from MOVES model; values are variable according to model input and vehicle class		EPA 2014b
Off-Road Transport	Diesel	0.771241	92106	EPA 2014a
	Gasoline	0.12178	92113	EPA 2014a
	Natural Gas	0.384	92112	EPA 2014a
Rail Transportation	Diesel	0.771241	92106	EPA 2014a
	Biodiesel	0.771241	92106	EPA 2014a

*Note: For modelling purposes, liquid petroleum gas and compressed natural gas vehicles are assumed to have similar PM and BC emissions characteristics as gasoline vehicles.

Table B–6 **Black Carbon/$PM_{2.5}$ Ratios for Agriculture Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Fuel Use		Kerosene & Stove Oil	0.1	91115	EPA 2014a
		Light Fuel Oil	0.1	91115	EPA 2014a
		Natural Gas	0.067	421072.5	EPA 2014a
		Natural Gas Liquids	0.067	421072.5	EPA 2014a

Table B–7 **Black Carbon / $PM_{2.5}$ Ratios for Commercial / Residential / Institutional Source Emission Calculations**

Sector	Subsector	$BC/PM_{2.5}$ fractions		Profile	Reference
		Description	Value (w/w)		
Commercial and Institutional Fuel Combustion		Kerosene & Stove Oil	0.1	91115	EPA 2014a
		Light Fuel Oil	0.1	91115	EPA 2014a
		Natural Gas	0.384	91112	EPA 2014a
		Natural Gas Liquids	0.384	91112	EPA 2014a
Construction Fuel Combustion		Kerosene & Stove Oil	0.1	91115	EPA 2014a
		Light Fuel Oil	0.1	91115	EPA 2014a
		Natural Gas	0.384	91112	EPA 2014a
Home Firewood Burning	Advanced Technology Fireplace	Non-Catalytic	0.055791381	92105	EPA 2014a
	Conventional Fireplace	With Glass Doors	0.055791381	92105	EPA 2014a
		Without Glass Doors	0.055791381	92105	EPA 2014a
	Fireplace Insert	Advanced Technology	0.055791381	92105	EPA 2014a
		Conventional	0.055791381	92105	EPA 2014a
	Wood Furnace	All	0.138	4704	EPA 2014a
	Pellet Stove	All	0.055791381	92105	EPA 2014a
	Wood Stove	Conventional	0.055791381	92105	EPA 2014a
		EPA Certified	0.055791381	92105	EPA 2014a
Residential Fuel Combustion		Kerosene & Stove Oil	0.1	91115	EPA 2014a
		Light Fuel Oil	0.1	91115	EPA 2014a
		Natural Gas	0.067	421072.5	EPA 2014a
		Natural Gas Liquids	0.067	421072.5	EPA 2014a

ANNEX C: **UNECE REPORT ON BLACK CARBON EMISSIONS**

Canada is using the UNECE report (template) and the associated Nomenclature for Reporting (NFR) codes for reporting its black carbon emissions internationally (Table C–1).

Table C–1 **2018 Canadian Black Carbon UNECE Report**

NFR Aggregation for Gridding and LPS (GNFR)	NFR Code	Long name	BC emissions (kt)			
			2013	2014	2015	2016
A_PublicPower	1A1a	Public electricity and heat production	0.21	0.23	0.24	0.24
B_Industry	1A1c	Manufacture of solid fuels and other energy industries	2.50	2.85	2.79	2.52
B_Industry	1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.00	0.00	0.00	0.00
B_Industry	1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	0.05	0.05	0.04	0.04
B_Industry	1A2d	Stationary combustion in manufacturing industries and construction: Pulp, paper and print	0.27	0.21	0.20	0.19
B_Industry	1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	0.01	0.02	0.02	0.02
B_Industry	1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.67	0.59	0.61	0.55
C_OtherStationaryComb	1A4ai	Commercial/institutional: Stationary	0.84	0.90	0.85	0.86
C_OtherStationaryComb	1A4bi	Residential: Stationary	11.84	11.77	11.68	11.74
D_Fugitive	1B2c	Venting and flaring (oil, gas, combined oil and gas)	0.17	0.19	0.20	0.21
F_RoadTransport	1A3bi	Road transport: Passenger cars	0.32	0.30	0.28	0.28
F_RoadTransport	1A3bii	Road transport: Light duty vehicles	0.33	0.32	0.33	0.35
F_RoadTransport	1A3biii	Road transport: Heavy duty vehicles and buses	7.00	6.36	5.68	5.45
F_RoadTransport	1A3biv	Road transport: Mopeds & motorcycles	0.00	0.00	0.00	0.00
G_Shipping	1A3di(ii)	International inland waterways	IE	IE	IE	IE
G_Shipping	1A3dii	National navigation (shipping)	2.81	2.81	1.26	1.28
H_Aviation	1A3ai(i)	International aviation LTO (civil)	0.02	0.02	0.02	0.02
H_Aviation	1A3aii(i)	Domestic aviation LTO (civil)	0.19	0.18	0.18	0.18
I_Offroad	1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	5.86	5.39	5.30	3.88
I_Offroad	1A3c	Railways	2.16	2.22	2.11	1.95
I_Offroad	1A4aii	Commercial/institutional: Mobile	0.80	0.74	0.76	0.64
I_Offroad	1A4bii	Residential: Household and gardening (mobile)	0.21	0.21	0.21	0.17
I_Offroad	1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	5.33	4.92	4.56	3.49
I_Offroad	1A4ciii	Agriculture/Forestry/Fishing: National fishing	IE	IE	IE	IE
I_Offroad	1A5b	Other, Mobile (including military, land based and recreational boats)	0.74	0.67	0.65	0.56
J_Waste	5C1bi	Industrial waste incineration	0.01	0.01	0.01	0.00
O_AviCruise	1A3ai(ii)	International aviation cruise (civil)	0.29	0.29	0.31	0.32
O_AviCruise	1A3aii(ii)	Domestic aviation cruise (civil)	0.16	0.16	0.15	0.15
Total			43	41	38	35

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